CRYOGENIC MACHINING OF HIGH PERFORMANCE MATERIALS

Vimal Dhokia, Alborz Shokrani, Stephen T. Newman
Department of Mechanical Engineering
Email: V.Dhokia@bath.ac.uk

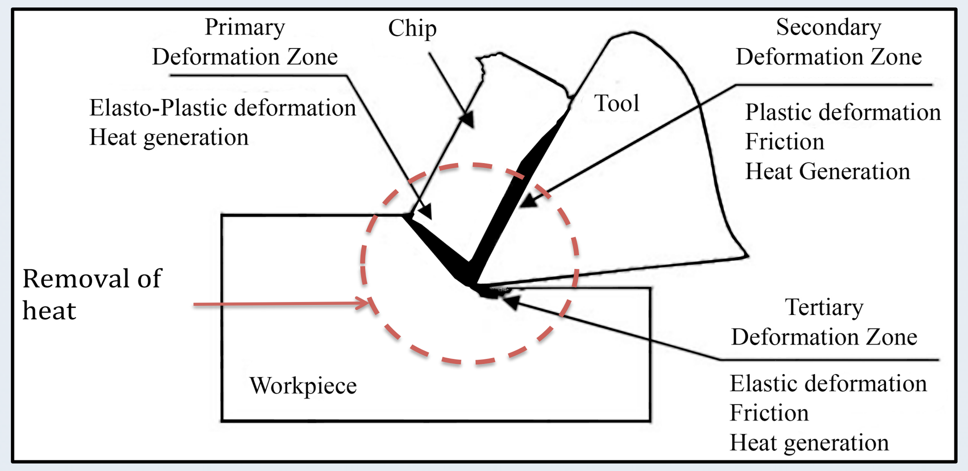
UNIVERSITY OF BATH

1. Introduction

The use of high performance materials such as Titanium alloys, Aluminum alloys (T6-T7) Cobalt Chrome, and Inconel 718 are continuing to increase in a diverse range of industries because of the enhanced and superior metallurgical properties they offer. However, as a consequence of these properties, processing of these materials presents a number of challenges.

Present methods involve oil and synthetic coolants and can result in the following:

- Significantly reduced tool life.
- Poor surface finishes as generated heat cannot be dissipated as a result of poor thermal conductivity and high thermal capacity.
- Conventional cutting fluids evaporate in contact with hot surfaces – formation of hot vapour films.
- High shear rates during machining can lead to adiabatic shear banding in certain materials.
- Non-uniform chip formation.
- Surface degradation.
- Reduced machinability.

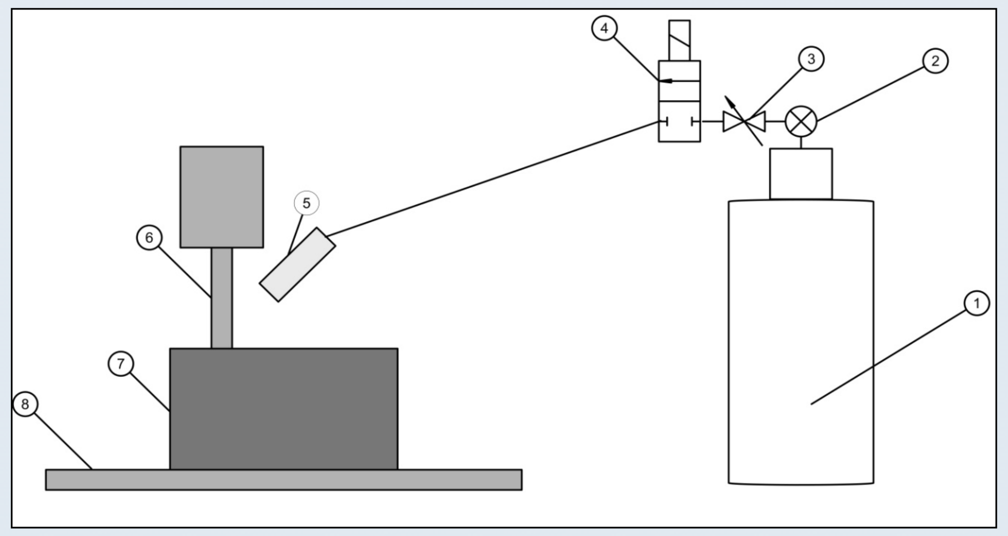


Rapid removal of heat is critical in machining of high performance materials.

2. Cryogenic CNC machining

A process currently being developed at the University of Bath is that of cryogenic CNC machining, where cryogens are used as a form of coolant to rapidly remove heat from the cutting zone and provide significant enhancements to the machining process.

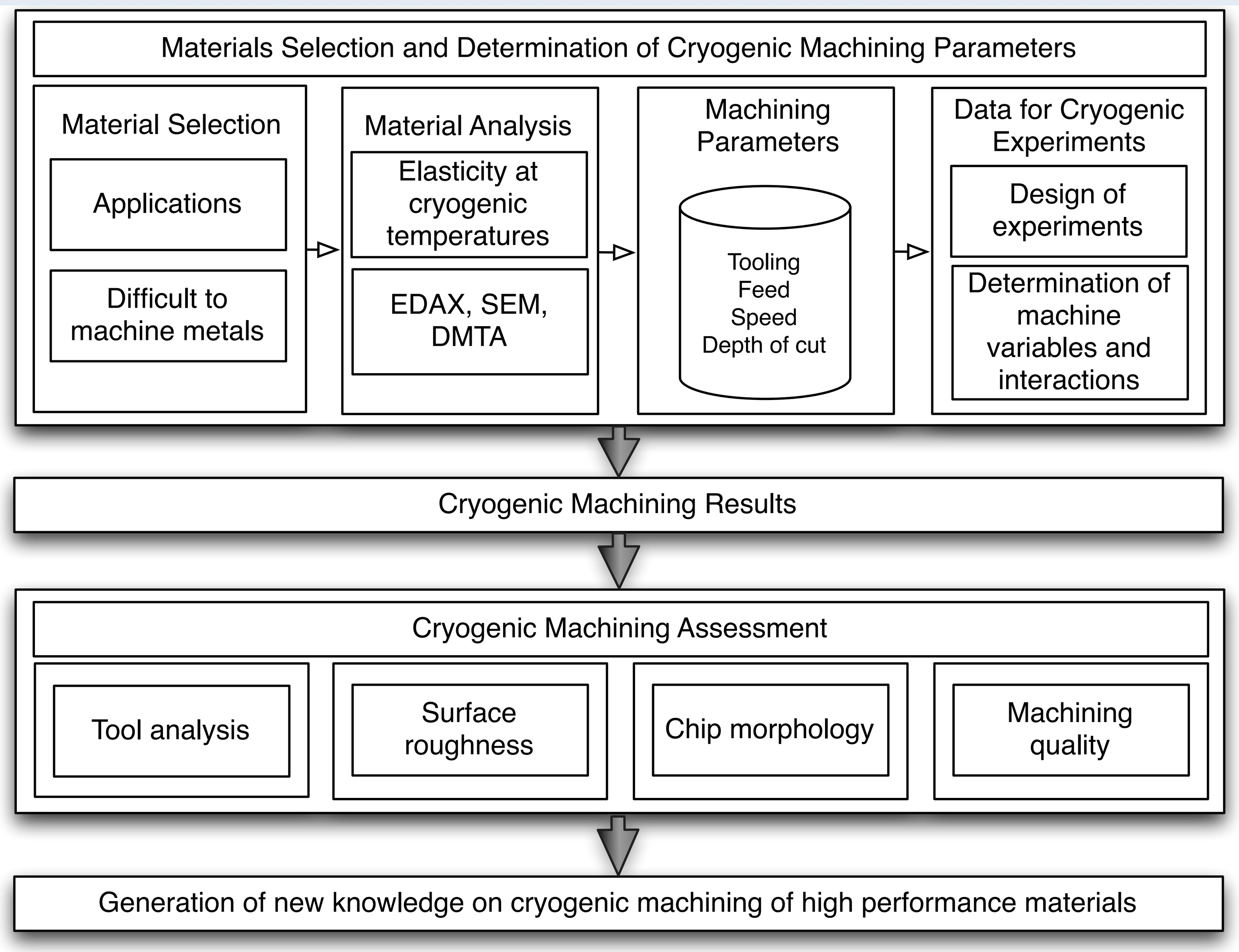
1. Liquid nitrogen in place of oil based coolants
2. Cryogenic spray jet systems
3. Removal of heat from the cutting zone
4. Different cooling methods



Schematic setup for cryogenic machining, 1-Liquid nitrogen Dewar, 2-pressure gauge, 3- gate valve, 4- solenoid on/off valve, 5- specially designed nozzle, 6- cutting tool, 7- workpiece, 8- machine table

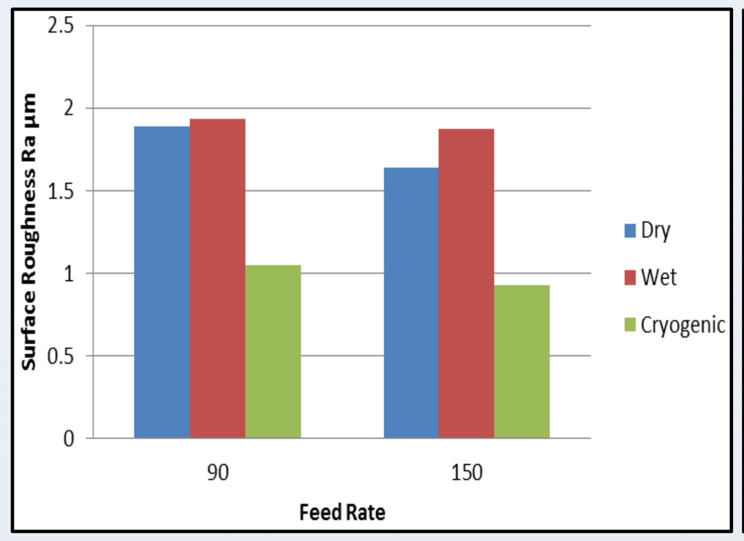
3. Methodology

The developed experimental methodology consists of two different phases and is used for capturing new knowledge on the cryogenic machining of high performance materials. A series of material analysis measures are conducted in phase one to determine optimum material dependent machining parameters. Experiments are subsequently conducted and results analysed in phase two.

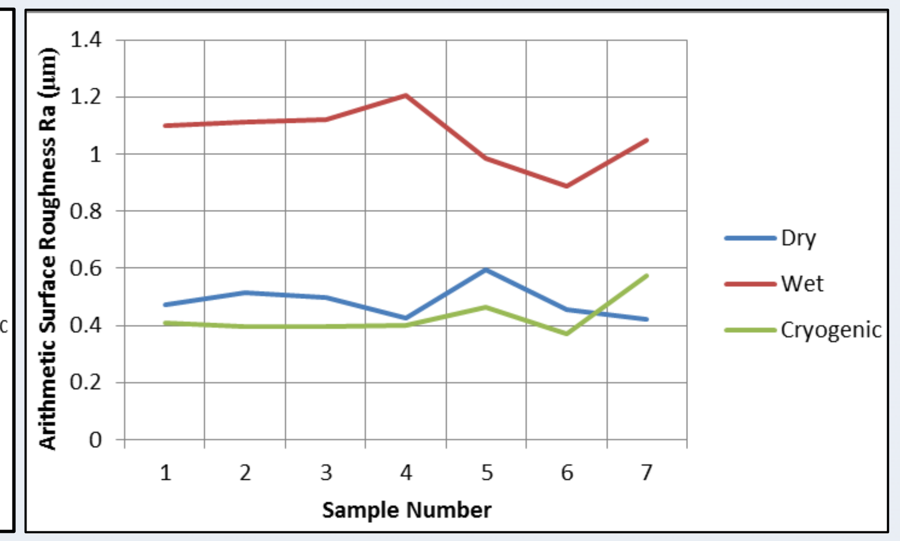


4. Results

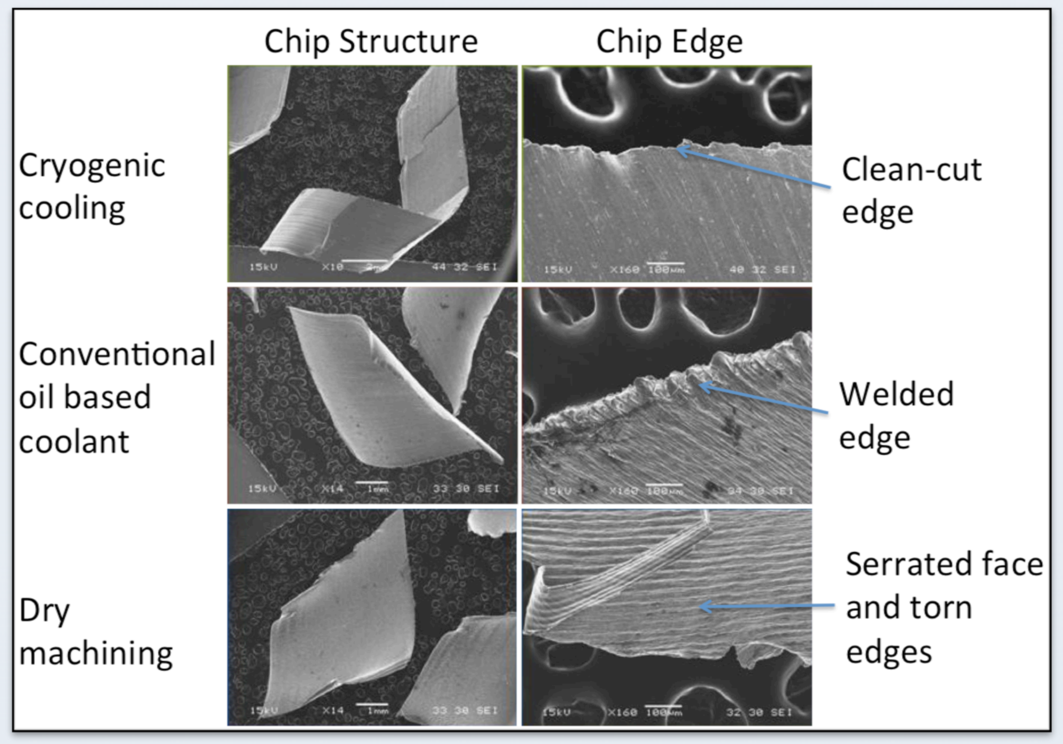
T6 Aluminium



Titanium alloy – Ti-6Al-4V



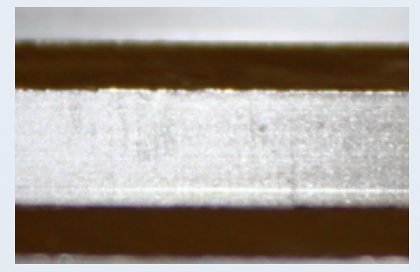
SEM T6 Aluminium chip examples



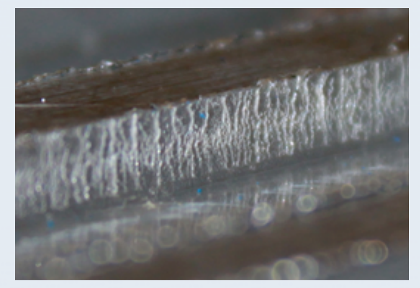
Chips produced under the cryogenic machining condition have a higher degree of surface finish and a more uniform edge as compared to dry and wet conditions. - An indication of lower friction and heat at the cutting zone.

Improved surface finish of machined parts (Titanium & Aluminium) under cryogenic cooling condition as lower cutting temperatures reduce smearing and chip re-deposition on the machined surface and tool. This effect is clearer on the side walls of the machined slots where higher temperatures together with high mechanical pressure result in very poor surface finish, smearing and material re-deposition in dry machining.

Cryogenic Machining



Dry Machining



5. Conclusions

The results demonstrate the efficacy and viability of using cryogenic technologies coupled with traditional CNC machining methods. In particular surface roughness reduced and machinability increased. When compared against conventional methods cryogenic machining provides the following:

- Surface roughness reduced by up to 50% for Titanium and 62% for Aluminum. Results for Inconel 718 also showed a 50% improvement in surface finish.
- Tool wear reduced, particularly in terms of cutter edge damage and reduced material re-deposition (60% improvement for Titanium).
- Chip formation was more uniform and cleaner for all tested materials.
- Increased machinability in terms of improved quality and MRR.